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ID #041

Engineering Component Life-Cycle Costs; Mapping Engineering Reliability Over a Planning Horizon

20 May 2008

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What's a component?

What is the planning horizon?

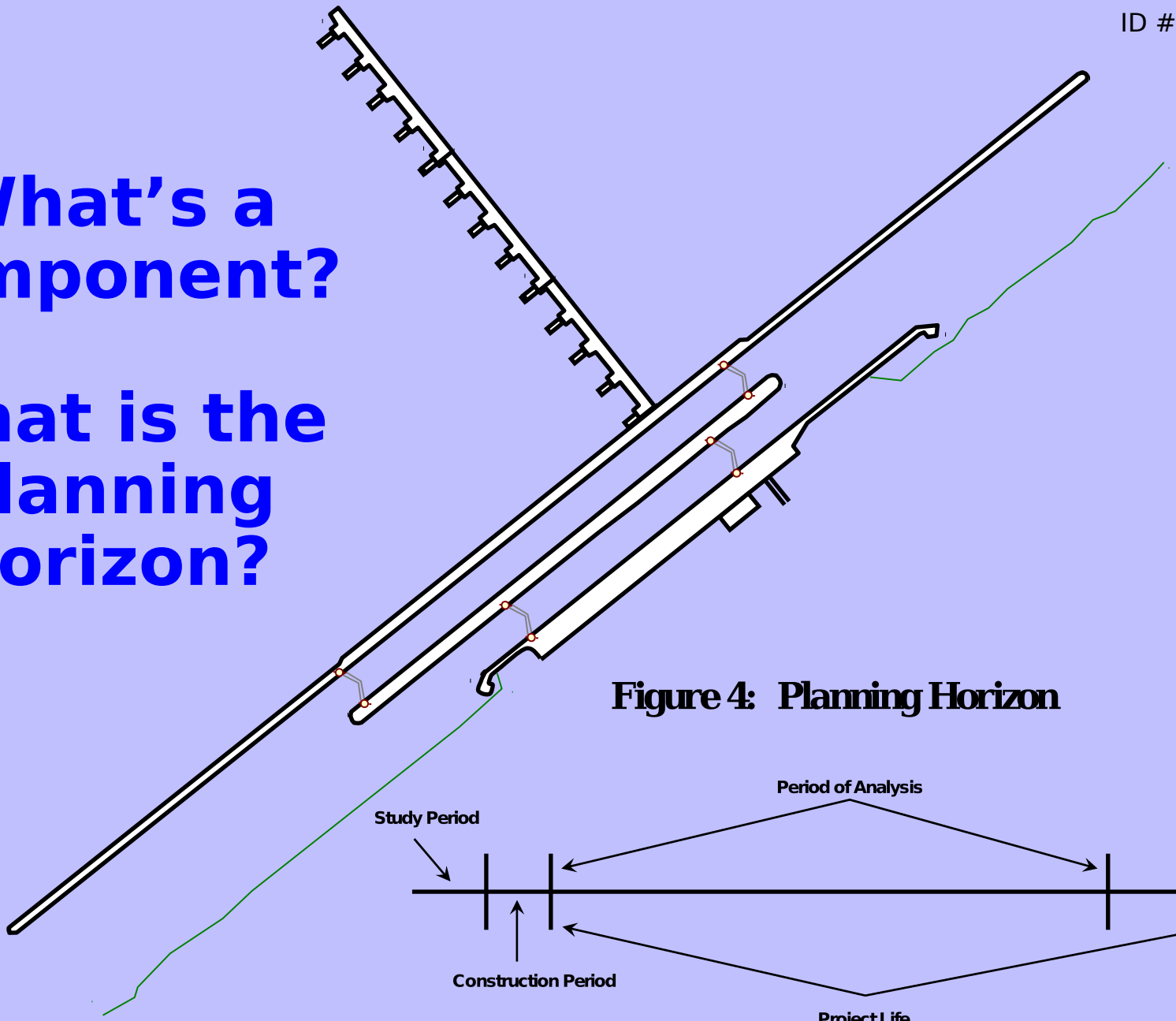
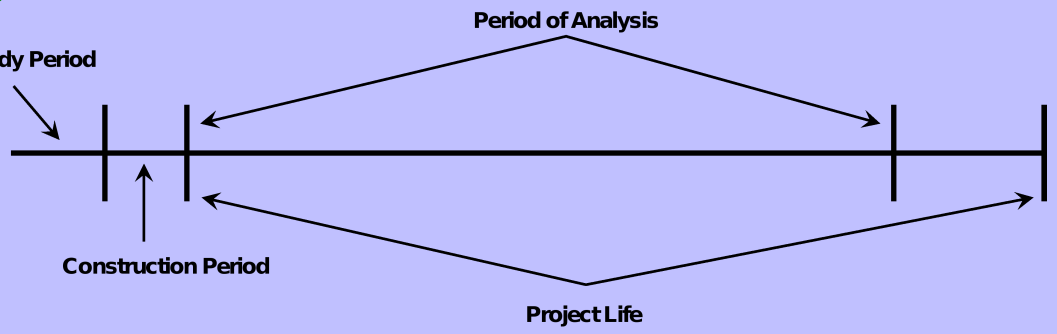


Figure 4: Planning Horizon



SOURCE: IWR Report 96-R-21, page 73

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Engineering Reliability Analysis

Reliability is a measure of a facility or component to perform its intended function under specified operating conditions for a given period of time.

$$P(f) + P(s) = 1$$

where: P(f) is the probability of failure (# failures / # simulations) and P(s) is the probability of survival (# sucessess / # simulations)

Probability of satisfactory performance is :

$$1 - p(f) = R = \text{Reliability}$$

Documented as Degradation Functions and

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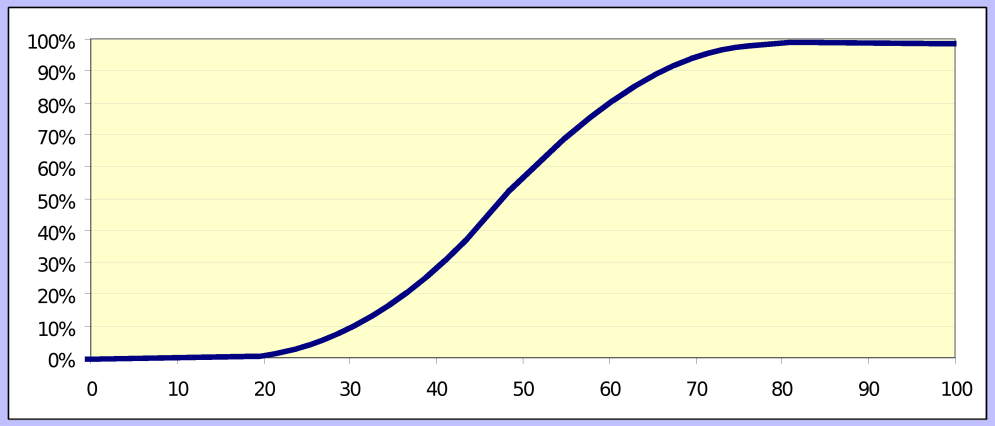
Component Degradation Functions (a.k.a. Hazard Function or PUP)

The hazard function, h(t), is the <u>conditional</u> probability of unsatisfactory performance of a facility or component in a specified time period *(or cycle load)*, given that it has survived up to the selected time period *(or cycle load)*.

$$h(t) = f(t)/R(t)$$

f(t) = the performance density function

R(t) = the reliability function



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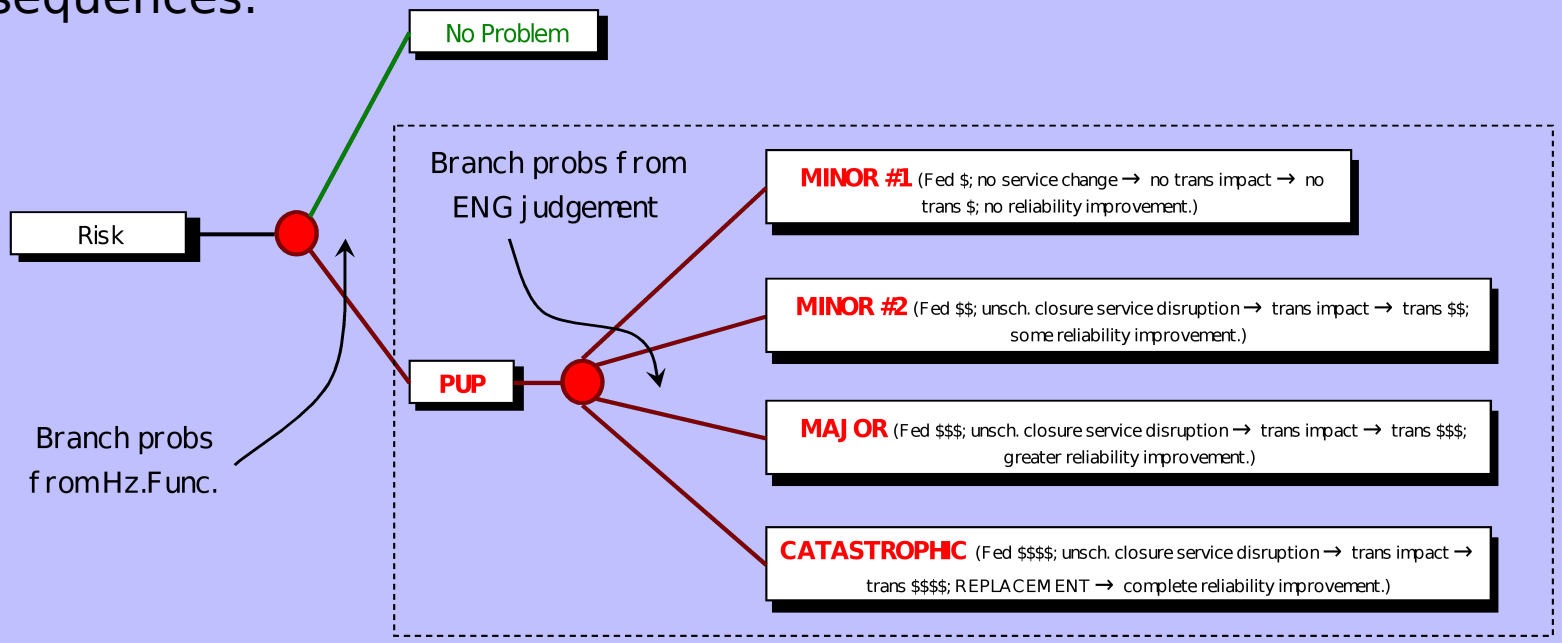
Event Trees → map risk consequences

Risk = potential to experience a loss. May be expressed as the product of the probability of an adverse event and its consequences.

Failure (PUP) consequences:

- Repair expense
- Repair duration
- Future reliability
- Future maintenance cycles (freq. & durations)


No Problem
Risk
Branch probs from ENG judgement
PUP
Branch probs from Hz.Func.
MINOR #1 (Fed $; no service change → no trans impact → no trans $; no reliability improvement.)
MINOR #2 (Fed $$; unsch. closure service disruption → trans impact → trans $$; some reliability improvement.)
MAJOR (Fed $$$; unsch. closure service disruption → trans impact → trans $$$; greater reliability improvement.)
CATASTROPHIC (Fed $$$$; unsch. closure service disruption → trans impact → trans $$$$; REPLACEMENT → complete reliability improvement.)

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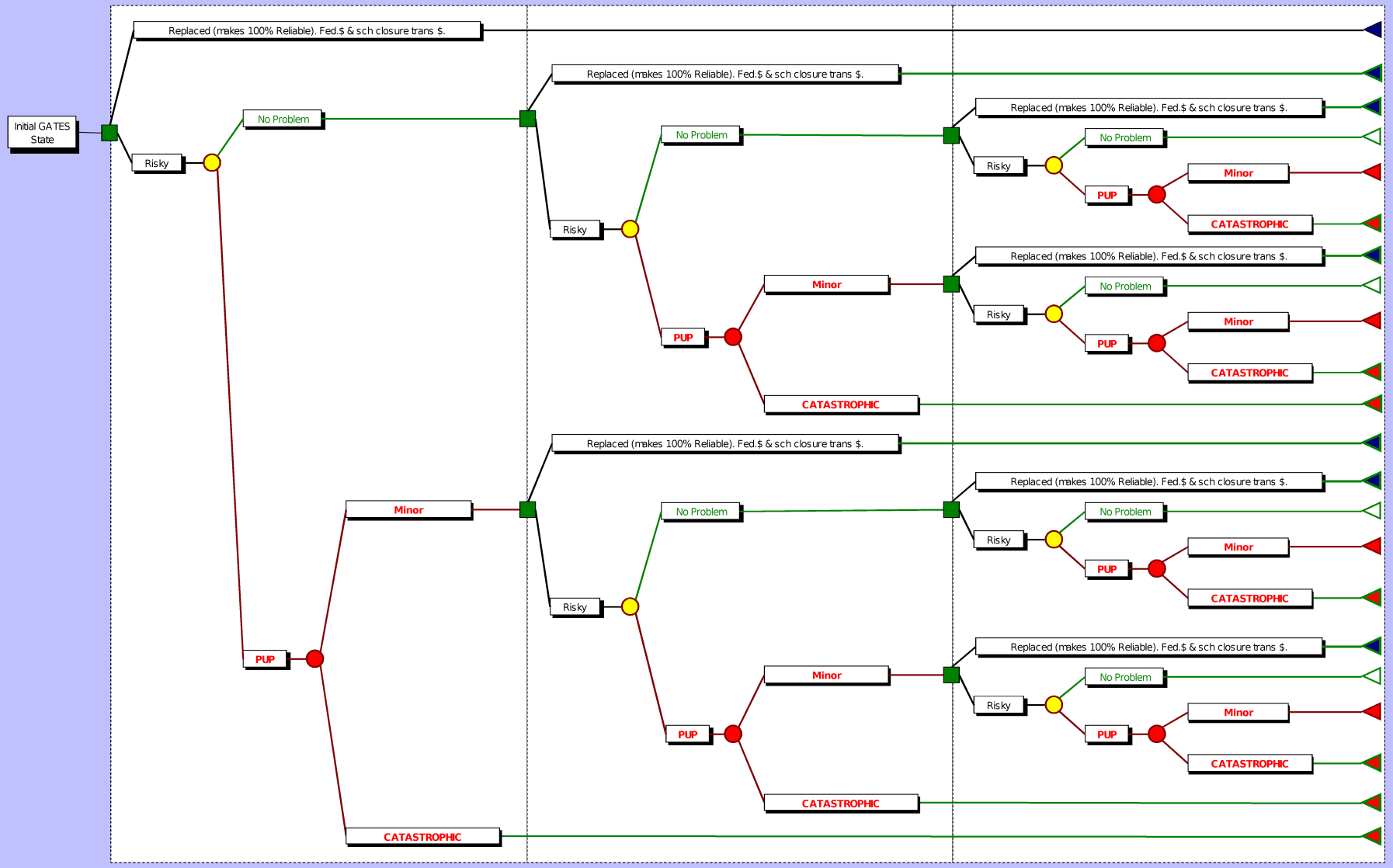
Event Tree → Event Tree



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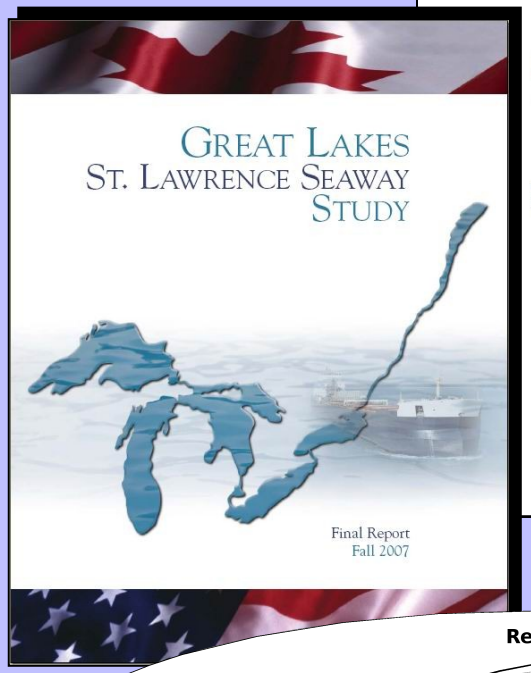
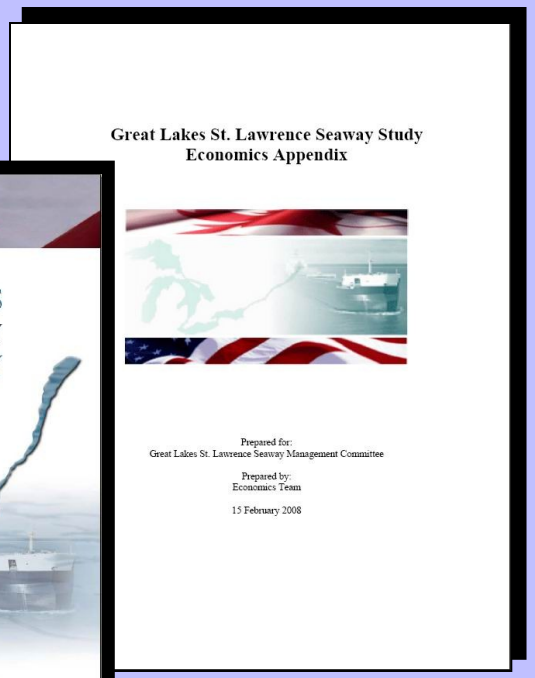
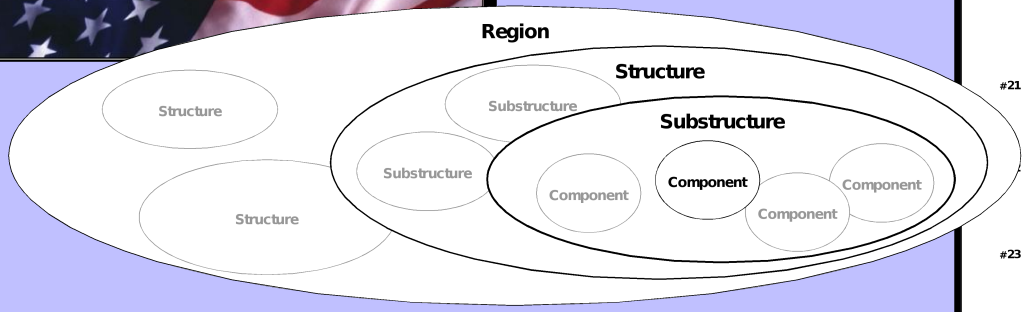




www.GLSLS-Study.com



ST. MARY'S REGION

MLO REGION

WELLAND CANAL REGION

Structure	Sub-Structure	Component
#13	#13-1 **Welland Lock 1**	#13-1-1 Upper Entrance Timber Tie-up Wall
	#13-2 Hwy Single Bascule Bridge 1	
Reach 1		
#14	#14-1 **Welland Lock 2**	#14-1-1 Upper EntranceTimber Tie-up Wall #14-1-2 Lower Entrance Timber Tie-up Wall
	#14-2 Hwy Single Bascule Bridge 3A	
Reach 2		
#15	#15-1 Hwy Twin Bascule Bridge 4	#15-1-1 Bridge 4 seat east abutment
#16	#16-1 **Welland Lock 3**	#16-1-1 Upper Entrance Timber Tie-up Wall #16-1-2 Lower Entrance Timber Tie-up Wall
Reach 3		
#17	#17-1 Hwy Single Vert.Lift Bridge 5	#17-1-1 Lift Bridge 5 machinery
#18	#18-3 (east) & #18-4 (west) RR Twin Bascule Bridge 6	#18-3-1 East Bascule Tread Plate #1 #18-3-2 East Bascule Tread Plate #2 #18-4-1 West Bascule Tread Plate #1 #18-4-2 West Bascule Tread Plate #2
	#18-1 (east) & #18-2 (west) **Welland Lock 4**	
#19	#19-1 (east) & #19-2 (west) **Welland Lock 5**	*no components analyzed*
#20	#20-1 (east) & #20-2 (west) **Welland Lock 6**	*no components analyzed*
Reach 4		
#21	#21-1 **Welland Lock 7**	*no components analyzed*
Reach 5		
	#22-1 Hwy Single Vert.Lift Bridge 11	#22-1-1 Lift Bridge 11 machinery
#23	#23-2 Hwy Single Bascule Bridge 19	
	#23-1 **Welland Lock 8**	*no components analyzed*
	#23-3 Hwy Single Bascule Bridge 19A	
#24	#24-1 Hwy Single Vert.Lift Bridge 21	#24-1-1 Lift Bridge 21 machinery

2008 PCoP – San Antonio, TX

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Component Degradation Functions (a.k.a. Hazard Function or PUP) - Failure Trigger -

Period-based and / or Event-based Failure Probabilities (hazard functions) … roll the probability dice on defined discrete time periods (e.g. daily) versus rolling the dice on events (e.g. lockage cycle) as they occur.

- some period & some event-based (possibly some both)
- complicating factors: winter shutdown & traffic seasonality.

Period-based and / or Event-based Simulation … divide time into discrete periods versus jumping to each event as it takes place.

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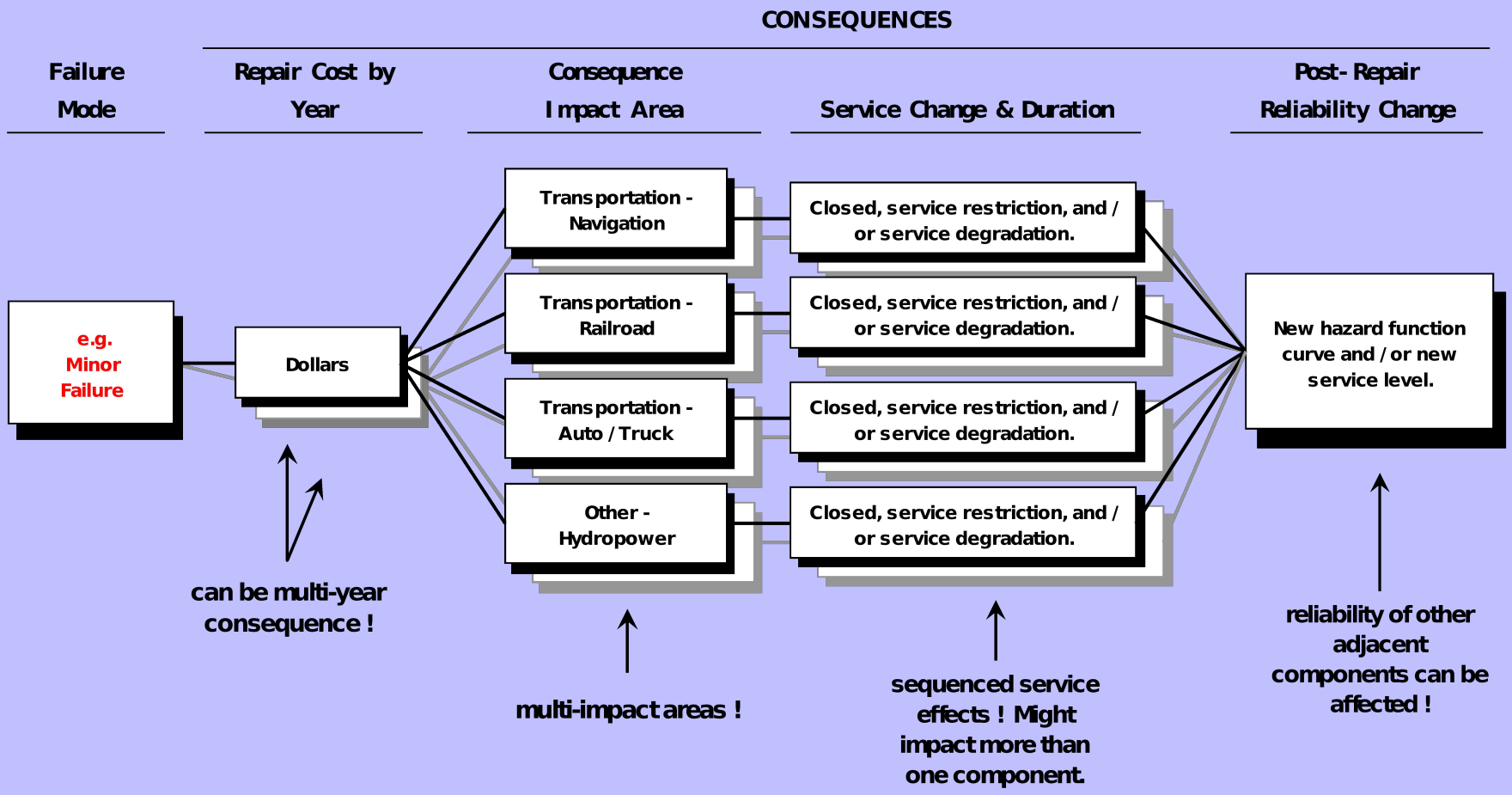
Event Tree Consequences


CONSEQUENCES
Failure Mode
Repair Cost by Year
Consequence Impact Area
Service Change & Duration
Post- Repair Reliability Change
e.g. Minor Failure
Dollars
Transportation - Navigation
Transportation - Railroad
Transportation - Auto / Truck
Other - Hydropower
Closed, service restriction, and / or service degradation.
Closed, service restriction, and / or service degradation.
Closed, service restriction, and / or service degradation.
Closed, service restriction, and / or service degradation.
New hazard function curve and / or new service level.
can be multi-year consequence !
multi-impact areas !
sequenced service effects ! Might impact more than one component.
reliability of other adjacent components can be affected !

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Component Risk Model (CRM)

Hazard Functions (period and/or event based … converted to daily probability)

Event-Trees (impact area, servuce & reliability change)

Historic and Forecasted Cycles (for event based probabilities)

Component Discription (location, type, ownership)

Maintenance Assumptions / Costs (e.g. normal vs. advanced)

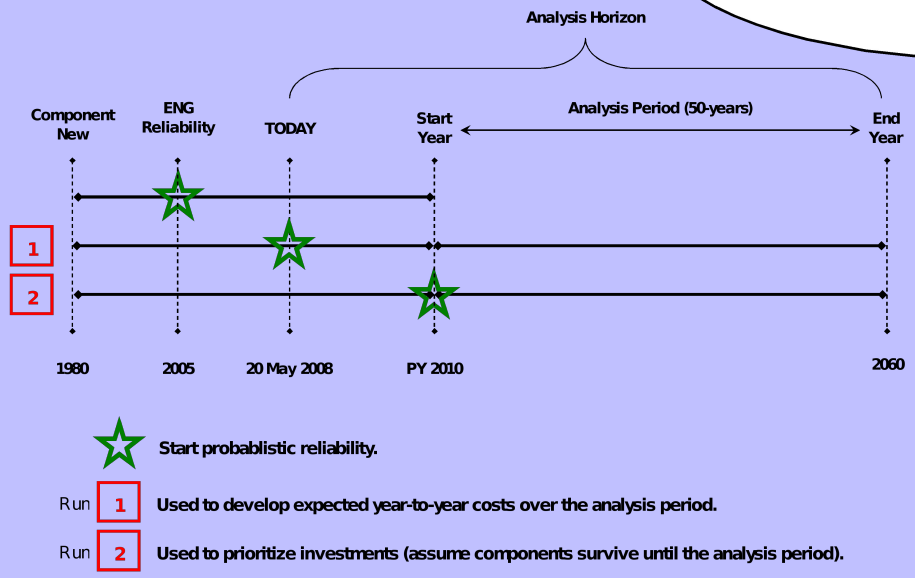
Sim Control (start, cycle forecast assumption, maintenance plan, scheduled reliability state changes)

Component Risk Model
daily simulation with event counter (C# with SQL Server - ORNL)

Simulated Navigation Service Disruptions (e.g. clousre, width restrictions, +processing time)

VTCS
system vessel simulation to est navigation delay & diversion costs

Repair and Maintenance Costs (period and/or event based)



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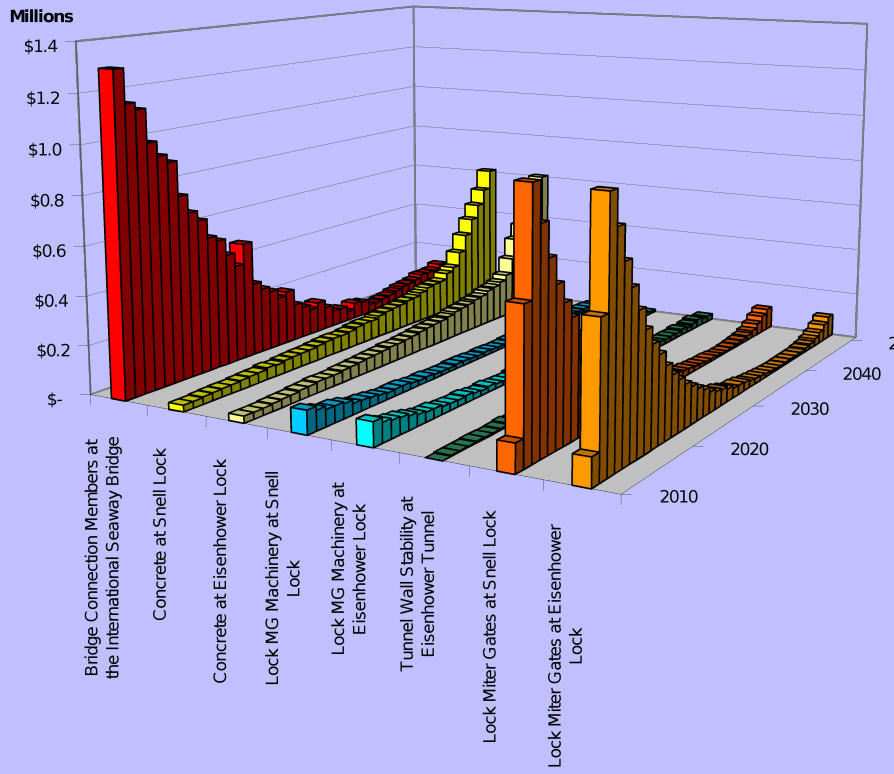
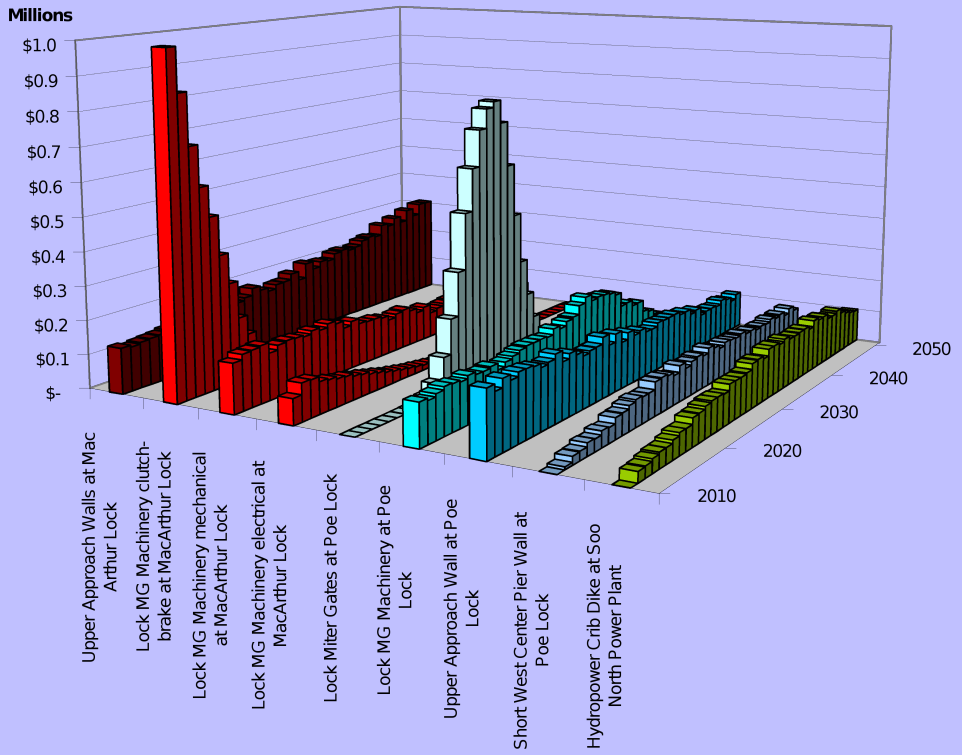
GLSLSS Results – Repair Costs by Year





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GLSLSS Results – Daily Probability of Service Disruption

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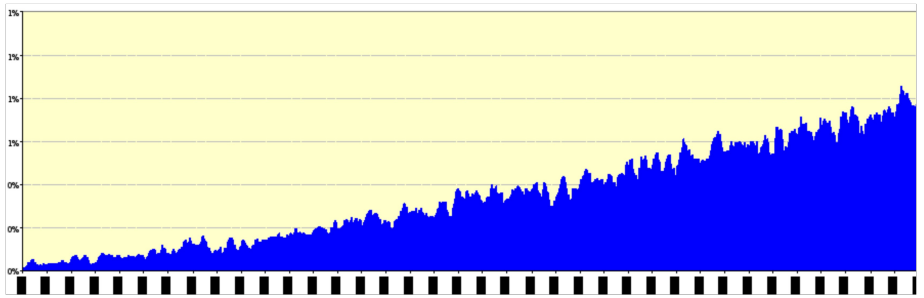

FIGURE 3.65 – Welland Bridge 5 Lift Machinery Vehicular Disruption Probability - Baseline Maintenance

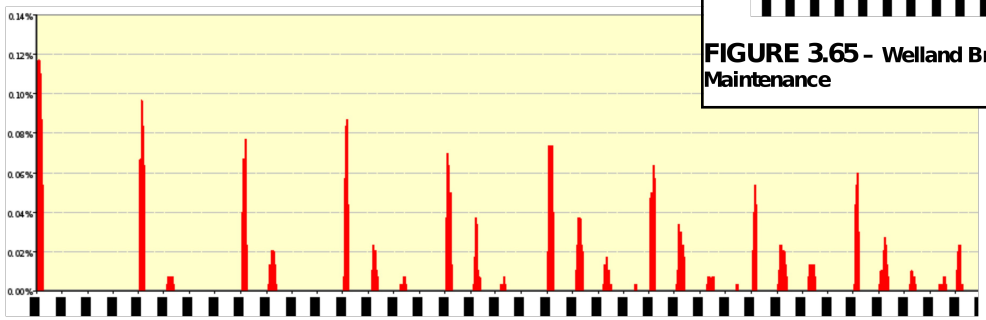

FIGURE 3.58 - Bridge #4 Seat Abutment Navigation Closure Probability By Day - Baseline Maintenance

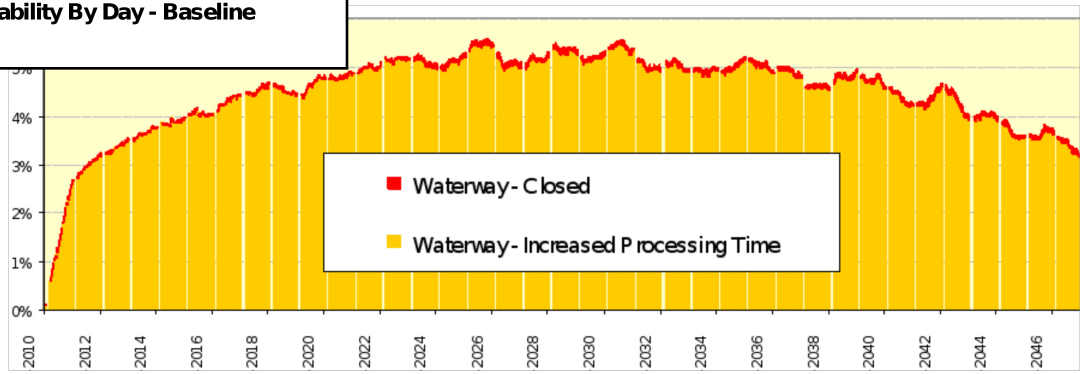

FIGURE 3.55 – Welland Lock 2 Tie-Up Wall Navigation Disruption Probability - Baseline Maintenance

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Some References

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QUESTIONS ?